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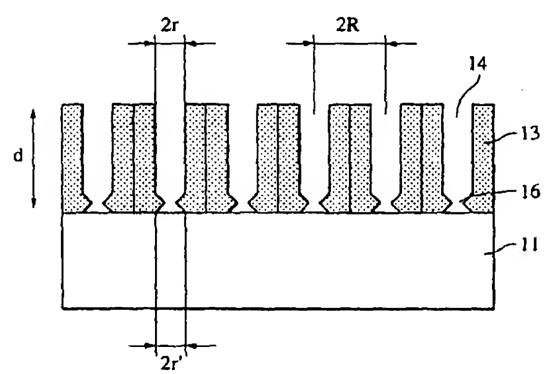
(54) Nanostructure, electron emitting device, carbon nanotube device, and method of producing the same

(57) The invention provides a nanostructure including an anodized film including nanoholes. The anodized film is formed on a substrate having a surface including at least one material selected from the group consisting of semiconductors, noble metals, Mn, Fe, Co, Ni, Cu and carbon. The nanoholes are cut completely through the anodized film from the surface of the anodized film to the surface of the substrate. The nanoholes have a first diameter at the surface of the anodized film and a second diameter at the surface of the substrate. The nanoholes are characterized in that either a constriction exists at a location between the surface of the anodized film and the surface of the substrate, or the second diameter is greater than the first diameter.

FIG. 2



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a nanostructure and a method of producing the same. The nanostructure produced by anodizing aluminum according to the present invention may be used in a wide variety of applications such as functional materials for use in electronic devices or micro devices. Specific examples include quantum effect devices, electrochemical sensors, biosensors, magnetic memories, magnetic devices, light emitting devices, photonic devices, solar cells, etc.

Description of the Related Art

[0002] In thin films, fine wires, and fine dots of metal or semiconductor, if motion of electrons is restricted within a region smaller than a particular length, the thin films, the fine wires, or the fine dots often exhibit special electric, optical, and/or chemical characteristics. From this point of view, materials having a fine structure (nanostructure) with a size smaller than 100 nm are attracting increasing attention as functional materials.

[0003] One known method of producing nanostructures is to employ a semiconductor processing technique including a fine pattern writing technique such as photolithography, electron-beam lithography, and X-ray lithography.

[0004] In addition to the production method described above, a self-forming technique is being developed. In this technique, a self-formed periodic structure is used to realize a novel nanostructure. This technique has a potential ability to produce a peculiar nanostructure including a finer structure, depending on a fine structure used as a base, than can be obtained by the conventional technique, and thus a lot of investigations are being performed.

[0005] An example of a self-formed peculiar structure is an anodized aluminum oxide film (refer to, for example, R. C. Furneaux, W. R. Rigby and A. P. Davidson, NATURE, Vol. 337, P. 147 (1989)). If an aluminum plate is anodized in an acid electrolyte, a porous oxide film is formed. Fig. 3A is a cross-sectional view schematically illustrating a nanostructure obtained by anodizing an aluminum plate 31 so as to form a porous anodized film 32 on the surface of the aluminum plate 31. Fig. 3B is a cross-sectional view schematically illustrating a nanostructure obtained by anodizing the surface of a thin aluminum film 34 formed for example on a semiconductor substrate 33 so as to form a porous anodized film 32. As can be seen from Figs. 3A and 3B, the feature of the anodized film is that it has a peculiar geometric structure including very small cylindrical holes (nanoholes) 35 which have diameters 2r ranging from several nm to several hundred nm and which are arranged in parallel at intervals of several ten nm to several hundred nm. The cylindrical nanoholes 35 have a large aspect ratio and have good uniformity in terms of the diameter over the entire length.

[0006] The diameter 2r of the nanoholes 35 and the hole-to-hole distance 2R can be controlled to a certain extent by adjusting the current and voltage during the anodization process. There is a barrier layer (aluminum oxide layer) 36 between the anodized film 32 and the aluminum substrate 31 or the aluminum film 34. A various applications are being attempted to take the advantages of such peculiar geometric structures obtained in anodized films. For example, anodized films may be used as films having high abrasion resistance and high dielectric strength. An anodized film may be separated from an underlying material and may be used as a filter. Furthermore, by filling the nanoholes with metal or semiconductor or by using a replica of nanoholes, other various application are also possible, such as coloring, magnetic storage media, EL devices, electrochromic devices, optical devices, solar cells, and gas sensors. The anodized film is also expected to have further various applications such as quantum effect devices (quantum fine wires, MIM (metal-insulator-metal) devices), molecular sensors using nanoholes as chemical reaction spaces, etc. (Masuda, Solid State Physics, 31, 493 (1996))

[0007] Producing nanostructures using semiconductor processing techniques is problematic because of low production yield and high apparatus cost. A simpler technique of producing nanostructures with good reproducibility is therefore desirable. From this point of view, the above-described self-forming techniques, in particular the technique of anodizing aluminum, have the advantage that nanostructures can be easily produced with high controllability. These techniques are also useful to produce large-area nanostructures.

[0008] The nanostructures shown in Fig. 3A and 3B have limitations in terms of shapes and applications because nanostructures can be formed only on the surface of an aluminum plate (film). For example, because the melting point of aluminum is as low as 660°C, the nanoholes formed on the surface of aluminum cannot be subjected to a heat treatment at temperatures higher than 660°C. Therefore, to use nanoholes as functional materials in various applications, it is necessary to develop a technique of forming an anodized film on a substrate with a high melting point without destroying its peculiar geometric structure, and also a technique of preventing generation of cracks at high temperatures.

[0009] On the other hand, to use the peculiar geometric structure of the anodized film in an electron device, an anodized film must be formed on a semiconductor substrate. In particular, a technique of forming an anodized film on a silicon substrate is important. If it is possible to form an anodized film on a silicon substrate, then it becomes possible to integrate a nanostructure with a silicon semiconductor device such as a diode and a tran-

sistor. This allows the nanostructure to be used in wider applications.

[0010] A technique of forming an anodized film including nanoholes on a silicon substrate is disclosed in Japanese Patent Laid-Open No. 7-272651. In this technique, an aluminum film is first formed on a silicon substrate, and then the aluminum film is converted into an anodized film. After that, the barrier layer of the anodized film, present at the bottom of the nanoholes, is removed. A metal layer (Au, Pt, Pd, Ni, Ag, Cu) capable of forming an eutectic alloy with silicon is then formed on the exposed parts of the silicon substrate and silicon capillary crystal is grown using the VLS method. In this technique, to produce nanoholes which are completely cut through an anodized film from its surface to a silicon substrate, the barrier layer at the bottom of the nanoholes is removed after anodizing the aluminum film. The removal of the barrier layer may be performed, for example, by means of etching using a chromic acid-based etchant or by means of keeping a silicon substrate, together with an opposite electrode electrically connected to the silicon substrate via an external wire, in a solution still after completion of anodization.

[0011] The inventors of the present invention have investigated the above-described technique disclosed in Japanese Patent Laid-Open No. 7-272651. The investigation has revealed that it is very difficult to completely anodize an aluminum film over its entire thickness such that a barrier layer remains at the bottom of all nanoholes 35. That is, the depth of nanoholes varies more or less, and thus it is difficult to produce a structure having a remaining barrier layer with an uniform thickness over a wide area as shown in Fig. 4. During the process of anodizing the aluminum film, the barrier layer is altered or lost in a very short time although the reason is not clear. As a result, the electrolyte comes into contact with the silicon substrate. Thus, oxidation of the silicon substrate and decomposition of the electrolyte occur. Although nanoholes having a remaining barrier layer can be formed in a certain area on the substrate, if the barrier layer is removed, then, as shown in Fig. 5, the diameter of the nanoholes 37 in the parts where the barrier layer is removed will not be uniform in the resulting structure. Furthermore, the shape varies greatly from one nanohole to another. In particular when nanoholes have a large depth, the anodized film tends to have a nonuniform thickness and anodization tends to occur nonuniformly. Thus, it is very difficult to form completely-cut-through nanoholes having an uniform shape with good repeatability.

SUMMARY OF THE INVENTION

[0012] The inventors of the present invention have carried out experiments and have determined that when an aluminum film, formed on a substrate having an electrically conductive layer including at least one element selected from the group consisting of Cu, Zn, Au, Pt, Pd, Ni, Fe, Co, and W, is anodized, the anodization current quickly increases at first and then a reduction in the anodization current occurs. Most nanoholes of the anodized film are broken if the anodization is continued further after the anodization current drops. However, if the anodization current is stopped immediately after the start of the anodization current drop, it is possible to obtain an anodized film having nanoholes completely cut through the anodized film from its surface to the electrically conductive surface. However, a further investigation has revealed that a considerable number of nanoholes produced by the above technique do not reach the electrically conductive surface, and the nanoholes do not have sufficient uniformity in shape. Thus, a further improvement of the technique is required.

[0013] In view of the above, it is a general object of the present invention to solve the above-described problems. More specifically, it is an object of the present invention to provide a nanostructure having an anodized film including completely-cut-through nanoholes having good uniformity of shape wherein the anodized film is formed on a substrate including at least one material selected from the group consisting of semiconductors, noble metals, and carbon. It is another object of the present invention to provide a device using such a nanostructure.

[0014] It is still another object of the present invention to provide a method of producing a nanostructure, in a highly reliable fashion, having an anodized film including completely-cut-through nanoholes having good uniformity of shape wherein the anodized film is formed on a substrate including at least one material selected from the group consisting of semiconductors, noble metals, and carbon. It is still another object of the present invention to provide a high-performance electron emitting device capable of emitting a large amount of electrons.

[0015] It is still another object of the present invention to provide a method of efficiently producing a carbon nanotube device which can be advantageously used in a high-performance electron emitting device.

[0016] According to a first aspect of the present invention, to achieve the above objects, there is provided a nanostructure comprising a substrate having a surface including at least one material selected from the group consisting of semiconductors, noble metals, Mn, Fe, Co, Ni, Cu and carbon. An anodized film having a nanohole is disposed on the surface of the substrate. The nanohole passes through the anodized film from the surface of the anodized film to the surface of the substrate, and has a first diameter at the surface of the anodized film and a second diameter at the surface of the substrate. The nanohole either has a constriction at a location between the surface of the anodized film and the surface of the substrate with a diameter smaller than the first and second diameters, or else the second diameter is greater than the first diameter.

[0017] The present invention has been achieved based on the knowledge obtained through the experi-

ments performed by the inventors of the present invention. That is, when a thin aluminum film is anodized after forming the thin aluminum film on a substrate having a surface including at least one material selected from the group consisting of semiconductors, noble metals, and carbon, a constant anodization current is observed over a certain period of time and then a reduction in the anodization current occurs. If the anodization is performed while monitoring the anodization current and the anodization is terminated when a particular change in current is detected, it is possible to obtain an anodized film including nanoholes having an uniform shape.

[0018] The nanoholes obtained by this method have a peculiar shape including a constricted part having a small diameter where the second diameter is greater than the first diameter. If the anodized film including the nanoholes having such a structure is used as an evaporation mask, then it is possible to produce a functional material having an extremely fine pattern. Furthermore, it is also possible to form an extremely fine pattern on the surface of a substrate by etching the surface of the substrate using the anodized film as an etching mask. The nanoholes with the second diameter greater than the first diameter are useful when it is required that an inclusion embedded by means of electro-deposition in the nanoholes be in good electrical contact with the surface of the substrate.

[0019] According to another aspect of the present invention, there is provided an electron emitting device comprising the nanostructure of the first aspect of the invention, wherein a carbon nanotube is embedded in the nanohole such that one end of the carbon nanotube is connected to the surface of the substrate. An electrode is disposed such that the electrode and the surface of the substrate face each other, and means for applying a voltage between the surface of the substrate and the electrode is provided.

[0020] According to still another aspect of the present invention, there is provided a method of producing a nanostructure comprising an anodized film including nanohole. The anodized film is formed on a substrate having a surface containing at least one material selected from the group consisting of semiconductors, noble metals, Mn, Fe, Co, Ni, Cu and carbon. The nanoholes are cut completely through the anodized film from the surface of the anodized film to the surface of the substrate. The method includes the steps of (i) forming a film containing aluminum on the substrate having a surface containing at least one material selected from the group consisting of semiconductors, noble metals, Mn, Fe, Co, Ni, Cu and carbon, and (ii) anodizing the film containing aluminum. In step (ii), the anodization is conducted while monitoring an anodization current, and the anodization of the film containing aluminum is terminated when a reduction in the anodization current from a steady-state value is detected.

[0021] According to still another aspect of the invention, there provided an electrochemical device including a nanostructure produced using any of above-described techniques according to the invention.

[0022] According to still another aspect of the present invention, there is provided a method of producing a carbon nanotube device. The method includes the steps of forming a film including aluminum on a substrate having a surface including an n-type semiconductor region anodizing the film including aluminum over the entire thickness thereof so as to form an anodized film having nanoholes, electro-depositing catalytic fine particles on the surface at the bottom of the nanoholes, and growing carbon nanotubes from the catalytic fine particles.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

Fig. 1 is a plan view schematically illustrating a nanostructure according to an embodiment of the present invention;

Fig. 2 is a cross-sectional view of Fig. 1 taken along line A-A;

Figs. 3A and 3B are, respectively, cross-sectional views schematically illustrating a conventional nanostructure on an aluminum plate and a semiconductor substrate;

Fig. 4 is a cross-sectional view schematically illustrating a nanostructure formed by anodizing an aluminum film on a semiconductor substrate over the entire thickness of the aluminum film according to a conventional nanostructure production technique;

Fig. 5 is a cross-sectional view of a nanostructure obtained by removing, by means of etching, the barrier layer at the bottom of the nanoholes of the nanostructure shown in Fig. 4 so as to obtain completely-cut-through nanoholes;

Fig. 6 is a schematic diagram illustrating an anodization apparatus;

Fig. 7 is a graph illustrating the anodization current as a function of time for aluminum films formed on various substrates;

Fig. 8 is a cross-sectional view schematically illustrating a nanostructure according to another embodiment of the present invention;

Fig. 9 is a graph illustrating the anodization current as a function of time for aluminum films formed on various substrates;

Figs. 10A and 10B are cross-sectional views schematically illustrating a nanostructure according to another embodiment of the present invention, formed on, respectively, a semiconductor substrate and on a conductive film on a substrate;

Fig. 11 is a cross-sectional view schematically illustrating a nanostructure obtained by embedding a filler in the nanoholes of the nanostructure shown in Fig. 10A;

Fig. 12A illustrates a structure obtained by etching a substrate using the anodized film shown in Fig. 2

as an etching mask;

Fig. 12B illustrates a structure obtained by evaporating gold on the surface of a substrate using the anodized film shown in Fig. 2 as an evaporation mask;

Fig. 13 is a cross-sectional view schematically illustrating a nanostructure obtained by embedding a filler in the nanoholes of the nanostructure shown in Fig. 2;

Fig. 14 is a cross-sectional view schematically illustrating a nanostructure obtained by embedding a metal multilayer in the nanoholes of the nanostructure shown in Fig. 2;

Fig. 15 is a cross-sectional view schematically illustrating a nanostructure obtained by embedding a filler in the nanoholes of the nanostructure shown in Fig. 8;

Fig. 16 is a cross-sectional view schematically illustrating a nanostructure obtained by embedding a metal multilayer in the nanoholes of the nanostructure shown in Fig. 8;

Fig. 17 is a schematic diagram illustrating a structure obtained by evaporating gold on the surface of a substrate using the anodized film with the nanostructure shown in Fig. 8 as a mask;

Fig. 18 is a cross-sectional view schematically illustrating a nanostructure obtained by embedding a carbon nanotube in the nanoholes of the nanostructure shown in Fig. 2;

Fig. 19 is a cross-sectional view schematically illustrating a nanostructure obtained by embedding a carbon nanotube in the nanoholes of the nanostructure shown in Fig. 8;

Fig. 20 is a cross-sectional view schematically illustrating an electron emitting device produced using the nanostructure shown in Fig. 18, according to an embodiment of the present invention;

Figs. 21A, 21B, 21C, and 21D illustrate a process of producing a nanostructure including nanoholes such that nanoholes located in a particular area have a particular function;

Fig. 22A is a cross-sectional view schematically illustrating a nanostructure produced using an electrically conductive substrate on which a patterned electric insulating layer is formed, and Fig. 22B is a cross-sectional view schematically illustrating a nanostructure produced using an electrically insulating substrate on which a patterned electrically conductive layer is formed;

Fig. 23A is a cross-sectional view schematically illustrating a nanostructure obtained by embedding a filler in particular nanoholes of the nanostructure shown in Fig. 22A, and Fig. 23B is a cross-sectional view schematically illustrating a nanostructure obtained by embedding a filler in particular nanoholes of the nanostructure shown in Fig. 22B;

Fig. 24 is a schematic diagram illustrating a structure obtained by etching the surface of a substrate using the anodized film with the nanostructure shown in Fig. 21D as a mask;

Fig. 25 is a cross-sectional view schematically illustrating a nanostructure obtained by embedding a metal multilayer in the nanoholes formed on the electrically conductive layer of the nanostructure shown in Fig. 22B;

Fig. 26 is a cross-sectional view schematically illustrating an electrochemical sensor that is an example of a device according to an embodiment of the present invention; and

Fig. 27 a cross-sectional view schematically illustrating an electrochemical sensor that is another example of a device according to an embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0024] First, the features and advantages of the present invention are described below.

Construction of Nanostructure

[0025] Fig. 1 is a plan view schematically illustrating a nanostructure (nanoholes formed on a semiconductor) according to an embodiment of the present invention. Fig. 2 is a cross-sectional view taken along line A-A of Fig. 1. In Figs. 1 and 2, reference numeral 11 denotes a semiconductor substrate, 13 denotes an anodized film, and 14 denotes a nanohole (a hole with a very small diameter) formed in the anodized film 13. The chief ingredients of the anodized aluminum film 13 are aluminum and oxygen. The anodized aluminum film 13 includes a great number of cylindrical nanoholes 14. The nanoholes 14 extend in a direction substantially perpendicular to the surface of the semiconductor substrate 11. The nanoholes 14 are parallel to each other and they are located at substantially uniform intervals. The nanoholes 14 are completely cut through the anodized film 13 from the surface of the anodized film 13 to the surface of the semiconductor substrate 11. Each nanohole 14 has a first diameter (2r) at the surface of the anodized film 13 and a second diameter (2r') at the surface of the semiconductor substrate 11. Furthermore, each nanohole 14 has a part (constricted part) 16 with a diameter smaller than the first and second diameters. The nanoholes tend to be formed at triangular lattice points as shown in Fig. 1. The diameter 2r of each nanohole ranges from a few nm to a few hundred nm and the diameter 2R ranges from a few ten nm to a few hundred nm.

Method of Producing Nanoholes

[0026] The nanoholes having the structure described above may be produced by anodizing an aluminum film formed on, for example, a semiconductor substrate such that the anodization is terminated when the anodi-

film and the surface of the substrate, or the second diameter is greater than the first diameter.

Claims

1. A nanostructure comprising:

    a substrate having a surface containing at least one material selected from the group consisting of semiconductors, noble metals, Mn, Fe, Co, Ni, Cu and carbon; and
    an anodized film disposed on the surface of said substrate, said anodized film having a nanohole,
    wherein said nanohole passes through said anodized film from the surface of said anodized film to the surface of said substrate, and said nanohole has a first diameter at the surface of said anodized film, and a second diameter at the surface of said substrate, and wherein said nanohole has a constriction at a location between the surface of said anodized film and the surface of said substrate, said constriction having a diameter smaller than said first and second diameters.

2. A nanostructure comprising:

    a substrate having a surface containing at least one material selected from the group consisting of semiconductors, noble metals, Mn, Fe, Co, Ni, Cu and carbon; and
    an anodized film disposed on the surface of said substrate, said anodized film having a nanohole,
    wherein said nanohole passes through said anodized film from the surface of said anodized film to the surface of said substrate, and said nanohole has a first diameter at the surface of said anodized film, and a second diameter at the surface of said substrate, and wherein said second diameter is greater than said first diameter.

3. A nanostructure according to Claim 1 or 2, wherein the surface of said substrate is formed of a semiconductor oxide.

4. A nanostructure according to Claim 3, wherein the surface of said substrate is porous.

5. A nanostructure according to Claim 1 or 2, wherein the semiconductor is Si.

6. A nanostructure according to Claim 1 or 2, wherein the noble metal is selected from the group consisting of Ag, Au, Pt, Pd, Ir, Rh, Os and Ru.

7. A nanostructure according to Claim 1 or 2, wherein the carbon is selected from the group consisting of graphite, glassy carbon and amorphous carbon.

8. A nanostructure according to Claim 1 or 2, wherein an inclusion is embedded in said nanohole.

9. A nanostructure according to Claim 1 or 2, wherein said anodized film has an additional nanohole and the surface of said substrate includes first and second regions which are different in characteristic.

10. A nanostructure according to Claim 9, wherein the characteristic is resistance.

11. A nanostructure according to Claim 9, wherein an inclusion is embedded only in the nanohole located on said first region.

12. A nanostructure according to Claim 9, wherein said first region is an n-type semiconductor region and said second region is a p-type semiconductor region.

13. A nanostructure according to Claim 9, wherein said first region is an electrically conductive region and said second region is an electrically insulating region.

14. A nanostructure according to Claim 13, wherein said first region is a semiconductor region.

15. A nanostructure according to Claim 14, wherein said semiconductor region is an n-type semiconductor region.

16. A nanostructure according to Claim 8, wherein said inclusion is a magnetic material.

17. A nanostructure according to Claim 16, wherein said magnetic material includes a ferromagnetic material and a non-magnetic material which are multilayered.

18. A nanostructure according to Claim 8, wherein a substance having a capability of emitting light is embedded in said nanohole.

19. A nanostructure according to Claim 18, wherein said substance having the capability of emitting light is a substance having a capability of emitting light by means of fluorescence.

20. A nanostructure according to Claim 8, wherein a substance having a carrier type opposite to that of the semiconductor forming the surface of said semiconductor is embedded in the nanoholes.

21. A nanostructure according to Claim 8, wherein the anodized film comprises aluminum oxide, and a substance having a dielectric constant different from that of the aluminum oxide is embedded in the nanohole.

22. A nanostructure according to Claim 8, wherein a carbon nanotube is embedded in the nanohole such that one end of said carbon nanotube is connected to the surface of said substrate.

23. A nanostructure according to Claim 8, wherein:

said substrate includes an n-type semiconductor surface region located under the nanohole; and
a carbon nanotube is embedded in the nanohole located on the n-type semiconductor region, with one end of said carbon nanotube is connected to the surface of said n-type semiconductor.

24. An electron emitting device comprising:

a nanostructure comprising a substrate having a surface containing at least one material selected from the group consisting of semiconductors, noble metals, Mn, Fe, Co, Ni, Cu and carbon, and an anodized film disposed on the surface of said substrate, said anodized film having a nanohole, a carbon nanotube which is embedded in the nanohole such that one end of said carbon nanotube is connected to the surface of said substrate; said nanohole passing through said anodized film from the surface of said anodized film to the surface of said substrate, wherein said nanohole has a first diameter at the surface of said anodized film, and a second diameter at the surface of said substrate, and wherein said nanohole has a constriction having a diameter smaller than said first and second diameters; at a location between the surface of said anodized film and the surface of said substrate,
an electrode disposed such that said electrode and the surface of said substrate face each other; and
means for applying a voltage between the surface of said substrate and said electrode.

25. An electron emitting device comprising:

a nanostructure comprising a substrate having a surface containing at least one material selected from the group consisting of semiconductors, noble metals, Mn, Fe, Co, Ni, Cu and carbon, and an anodized film disposed on the surface of said substrate, said anodized film having a nanohole, a carbon nanotube which is embedded in the nanohole such that one end of said carbon nanotube is connected to the surface of said substrate; said nanohole passing through said anodized film from the surface of said anodized film to the surface of said substrate, wherein said nanohole has a first diameter at the surface of said anodized film, and a second diameter at the surface of said substrate, and wherein said second diameter is greater than said first diameter;
an electrode disposed such that said electrode and the surface of said substrate face each other; and
means for applying a voltage between the surface of said substrate and said electrode.

26. A method of producing a nanostructure comprising an anodized film including a nanohole on a substrate having a surface containing at least one material selected from the group consisting of semiconductors, noble metals, Mn, Fe, Co, Ni, Cu and carbon, said nanoholes passing through said anodized film from the surface of said anodized film to the surface of said substrate, wherein said method comprising the steps of:

(i) forming a film containing aluminum on the substrate having a surface containing at least one material selected from the group consisting of semiconductors, noble metals, Mn, Fe, Co, Ni, Cu and carbon; and
(ii) anodizing said film containing aluminum, wherein in step (ii) the anodization is conducted while monitoring an anodization current and the anodization of said film containing aluminum terminates when a reduction in said anodization current from a steady-state value is detected.

27. A method of producing a nanostructure according to Claim 26, wherein the anodization terminates when the anodization current is decreased from the steady-state value to 95% or below of the steady-state value.

28. A method of producing a nanostructure according to Claim 26, wherein an anodization voltage applied to said film including aluminum is supplied from the substrate side.

29. A method of producing a nanostructure according to Claim 26, further comprising the step of expanding the diameter of the nanoholes by means of etching, after completion of said anodizing step.

30. A method of producing a nanostructure according to Claim 26, further comprising the step of forming

FIG. 11

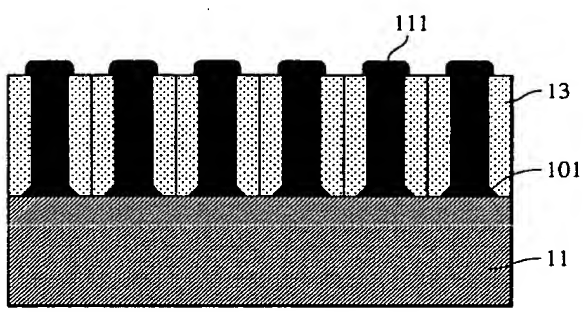

FIG. 20